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Evaluating use of neutral electrolysed water for cleaning near-patient surfaces

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A poster summarising this work was shown at ECCMID, Barcelona, 2014 (eP269).

A previous version of Figure 3 was presented at ECCMID (Barcelona) and APIC 2013 (Gold Coast) and included in a review for Clinical Microbiology Reviews.

Word count: 2384

Abstract

Objective:

This study aimed to monitor the microbiological effect of cleaning near-patient sites over a 48 hour period with a novel disinfectant, electrolysed water.

Setting:

One acute care of the elderly ward in a district general hospital in Scotland.

Methods:

Lockers, left and right cot-sides and overbed tables in 30 bed spaces were screened for aerobic colony counts (ACC), methicillin-susceptible *Staphylococcus aureus* (MSSA) and methicillin-resistant *S. aureus* (MRSA) before cleaning with electrolysed water. Sites were rescreened at varying intervals from 1- 48 hours after cleaning. Microbial growth was quantified as cfu/cm² and presence or not of MSSA and MRSA for each site. The study was repeated three times at monthly intervals.

Results:

There was an early and significant reduction in average ACC (360 sampled sites) from a pre-clean level of 4.3 to 1.65 cfu/cm² at one hour after disinfectant cleaning ($p < 0.0001$). Average counts then increased to 3.53 cfu/cm² at 24 hours and 3.68 cfu/cm² at 48 hours. Total MSSA/MRSA (34 isolates) declined by 71% at four hours after cleaning, but then increased to 155% (53 isolates) pre-clean levels at 24 hours.

Conclusions:

Cleaning with electrolysed water reduced ACC and staphylococci on surfaces beside patients. ACC remained below pre-clean levels at 48 hours but MSSA/MRSA counts exceeded original levels at 24 hours after cleaning. While disinfectant cleaning quickly reduces bioburden, further investigation is required to clarify the reasons for rebound contamination of pathogens at near-patient sites.

Introduction

Hospital pathogens such as methicillin-resistant *Staphylococcus aureus* (MRSA) can persist in the healthcare environment for months.¹ The most important reservoirs are hand-touch sites beside the patient, especially bedside locker, overbed table and bed frame.²⁻⁵ High levels of microbial flora on these surfaces are associated with increased risk of finding methicillin-susceptible *S.aureus* (MSSA) and MRSA.³

Current UK cleaning regimens specify detergent-cleaning for near-patient furniture and beds, unless there are specific recommendations for disinfectant use.^{6,7} The usual choice is sodium hypochlorite, which is toxic and has to be freshly prepared.⁷ Neutral

electrolysed water is based on a stable form of hypochlorous acid (Ph. 6-8) produced by passing an electric current through water with added salt.⁸ This product might be useful for hospital cleaning, given microbiocidal effects, low toxicity, long shelf-life and promising performance in care homes.^{9,10}

The aim of this study was to evaluate the impact of cleaning near-patient sites with electrolysed water on an acute hospital ward. Surfaces were screened before cleaning and then at varying intervals afterwards using standardised methods. We measured the immediate effect of disinfection and rate of recontamination over time. We also aimed to compare the effect of electrolysed water against data from a previous study where identical sites on a similar ward were cleaned using detergent only.¹¹

Setting

One acute care of the elderly ward in a 450-bedded NHS hospital was chosen as the study ward. The 30-bedded ward runs at 100% bed occupancy, with patients resident in six ensuite single rooms and four bays each containing six beds. Whilst patients of either sex can reside in the single rooms, three of the four bays accommodated female patients.

Methods

Four sites (bedside locker; left cot-side; overbed table; right cot-side) in 30 bed-spaces were screened using standardised microbiological methods for assessing surface cleanliness.^{12,13} Each site was then sprayed with 1.5 ml electrolysed water

(Salvesan™, Aqualution Ltd., UK) and wiped clean with detergent wipes 10-15 seconds later (Tuffie™ detergent wipes, Vernacare Ltd, Bolton, UK). One wipe was allocated for each site; four for each bed space. The study was repeated three times (phases 1-3) over a four month period in order to supply all data in triplicate.¹¹ Each phase was carried out independently, with the same screening protocol performed before, and after, cleaning. Beds and lockers are normally cleaned daily using detergent, i.e. approximately 22 hours before the study, with overbed tables cleaned after supper the previous evening, i.e. 12 hours before initial screening.

Two senior physicians performed the cleaning for each phase after training and assessment using microbiological methods. Study personnel wore freshly laundered overalls and washed hands with soap and water before, and during, screening and cleaning. Sites were rescreened at one hour; two hours; four hours; eight hours; 12 hours; 24 hours; and 48 hours after cleaning. Pre-clean screening began at 7am, followed by disinfectant cleaning in order to screen sites one hour after cleaning. Screening and cleaning adhered to a planned systematic programme so that each site was sampled at the same time intervals after cleaning. The 24 hour post-clean screening was initiated at 8am on the following day, and a final screen at 8am two days later (48 hours after cleaning).

Normal ward care for patients continued throughout the study, including routine cleaning of floors and toilet facilities delivered by domestic staff. No further cleaning of study sites, usually cleaned by nurses, took place until after the 48 hour screen other than attention to spillages. The protocol was discussed with domestic managers

and senior nurses in order to co-ordinate the study with routine ward practices. Ethical exemption was obtained from NHS Lanarkshire Research & Development.

Microbiology

Screening was performed using dipslides (Hygiena Int., Watford, UK), coated with nutrient and staphylococcal selective (Baird Parker) agars.^{3, 11-13} After sampling, dipslides were incubated for 48-72 hours according to laboratory protocol. Slide placement at each site was performed systematically in accordance with a pre-determined template so that slides did not sample areas previously screened.

Growth on nutrient agar supplied total aerobic colony counts (ACC) per cm², classified as no growth (NG); scanty growth (SG) <2.5 cfu/cm²; light growth (LG) 2.5-12 cfu/cm²; moderate growth (MG) 12-40 cfu/cm²; or heavy growth (>40 cfu/cm²).^{3,11,13} Selective agar highlighted coagulase-positive staphylococci, which were sub-cultured onto blood agar and identified. Hygiene standards have been proposed whereby ACC >5 cfu/cm² and/or presence of MSSA/MRSA at a hand-touch site indicates increased infection risk for patients.¹²⁻¹⁴

The methods duplicate those utilised for a previous study, performed by the authors six months earlier.¹¹ This study took place in an identical ward situated on the floor below in the same building. Both wards belong to the same unit, with similar case-mix, patient turnover, bed occupancy rates and staffing. They have the same lay-out, design and cleaning protocols and are managed by one clinical team. The same four

sites were screened before cleaning with detergent wipes and then rescreened at the same intervals after cleaning. Dipslides were processed as already described.¹¹

Statistical analyses

All data were subjected to statistical analyses. Each of the four sites around 30 beds at time $T = 0; 1, 2, 4, 8, 12, 24$ and 48 hours supplied an ACC categorised as indicated, along with numbers of MSSA/MRSA isolates. Each study phase provided a series of results for 30 x 4 sites, ultimately giving data for 360 sites. We compared total mean ACC against time, and site, in order to ascertain recontamination rate after cleaning. Total MSSA and MRSA were also calculated and plotted over time. Data were analysed for single rooms vs multiple patient bays.

This was an observational study and analysis of variance methods were used to assess the importance of time from cleaning, site and phase on total ACC for four sites beside 30 beds. The main investigation centred on modelling ACC trends over time using a linear regression model. We assumed normal distribution for total ACC and the assumptions of the model, including the absence of serial correlation, were validated through residual plots. Two way interactions were tested, using F tests at the pre-specified 1% significance level, as these were of secondary importance, while the main effects were tested at the 5% level. Poisson regression was employed for the analysis of numbers of MSSA/MRSA detected, with a chi-squared deviance test used.

Results

Cleaning with electrolysed water resulted in an immediate reduction in ACC at each site for all phases (Table). Figure 1 shows the mean ACC (cfu/cm²) and number of MSSA/MRSA isolates at all sites and screening times. Overall ACC decreased from 4.3 cfu/cm² before cleaning to 1.65 cfu/cm² at one hour after cleaning ($p < 0.0001$). This level gradually increased to 3.68 cfu/cm² at 48 hours after cleaning, which was less than that obtained before cleaning.

The reduction in average ACC occurred for all four sites after cleaning (Table; Fig 1). The pattern is similar for each site with ACC significantly lower than baseline for 1-12 hours. There is a return to baseline levels at 24 hours for two sites (locker and right cot-side) and for all sites by 48 hours. Microbial recovery was higher for overbed tables than from lockers and cot-sides. The patterns of recovery over time are different for each site and this is primarily due to the different pattern for the bedside locker compared with the other three sites (interaction test: $p = 0.0028$).

The reduction profile of viable MSSA/MRSA differed from ACC since the highest numbers were found at 24 hours, not 48 hours, after cleaning (Table; Fig 1). There are significant differences between phases ($p < 0.0001$), sites ($p < 0.0001$) and times ($p < 0.0001$). The total number of isolates for all three phases reduced by 71% from 34 isolates (pre-clean) to 10 isolates (29%) at 4 hours after cleaning. The numbers then increased to reach the highest level of 53 isolates (155%) at 24 hours, with 36 isolates (106%) recovered at 48 hours. Relative to the locker (56 isolates) there were fewer MSSA/MRSA recovered from the cot-sides (27 and 42 isolates), with the highest number overall from overbed tables (85 isolates).

Given relatively large numbers of staphylococci, MSSA and MRSA were examined independently (data not shown). For MRSA, there were no differences between phases ($p = 0.683$), nor over time, ($p = 0.289$), but MRSA was recovered from the overbed table ($p = 0.006$) more frequently than from the other sites. MSSA data was similar to total MSSA/MRSA data since the number of MRSA isolates recovered was relatively small compared with MSSA. There were no known patient clusters of either MSSA or MRSA in the ward during the study.

Sites in six single rooms (20% total beds) yielded proportionately similar total ACC compared with multi-bedded room sites before, and one hour after, cleaning (Table). Lower ACC were recovered from single rooms than multi-bedded rooms at 2-8 hours after cleaning but reached proportionately higher levels at 48 hours than for multi-bedded rooms. These differences are not statistically significant over time ($p = 0.28$), nor are there any differences in average ACC between single rooms and multi-bedded rooms (mean difference of 0.07, 95% CI 0.53, -0.39, ACC/cm², per bed, $p = 0.76$). Single room sites yielded proportionately more staphylococci before cleaning when compared with multi-bedded rooms ($p < 0.0001$), probably due to isolated MRSA patients during two phases. The apparent rebound in total MSSA/MRSA at 24 hours occurred in single rooms as well as multi-bedded rooms (Table).

In the previous study using detergent, the average ACC decreased from a pre-clean level of 6.72 cfu/cm² to 3.46 cfu/cm² at four hours after cleaning ($p < 0.0001$).¹¹

Although pre-clean ACC are lower in the present study, the effects on microbial load and MSSA/MRSA after both types of cleaning can be compared. Figure 2 shows % reduction of ACC before and after each type of cleaning over 48 hours. ACC

decreased more rapidly following exposure to disinfectant and achieved a relatively lower level (49% reduction of ACC for detergent vs. 63% reduction for disinfectant at 4 hours, though the confidence intervals overlap). There is little difference for levels of accumulated ACC at 8, 12, 24 and 48 hours for both types of cleaning.¹¹

Figure 3 shows % reduction of number of MSSA/MRSA isolates after detergent and disinfectant cleaning. Total staphylococci decreased to a minimum level at four hours in both studies, but whilst numbers returned to pre-clean levels at 48 hours after detergent, the number of isolates retrieved at 24 hours after disinfectant greatly superseded original levels, though not at 48 hours.

Discussion

This study sought to demonstrate the effect on bioburden at near-patient sites on an acute ward after cleaning with a novel disinfectant (electrolysed water). We also wanted to establish how quickly microbial levels accumulated after cleaning, having investigated this previously.¹¹ Disinfectant cleaning rapidly reduced ACC on screened surfaces, with levels at 48 hours the same or less than those obtained at the pre-cleaning stage. In contrast, the number of MSSA/MRSA isolates reached a minimum level at four hours but then demonstrated an unexpected surge at 24 hours.

This study has some limitations. Despite allowing intervals of at least one month between phases, there may have been a Hawthorne effect by staff between, and during, study phases. Staff invariably respond to any measure of cleaning activity by improving performance.⁶ Secondly, we did not know how well study sites were

cleaned the day before the cleaning initiative, although pre-clean ACC levels were similar for all sites and phases (Table). Comparing this study and the one previously, it is possible that spray delivery of electrolysed water might have encouraged dispersal of bioburden aside from any microbiocidal impact. Certainly, overall levels of bioburden were lower throughout this study, initially attributed to seasonal differences. Finally, there are no data on intensity of activity on the ward during each phase, including contributions from air, ambient temperature and humidity toward recontamination of screened sites. The ward was fully occupied throughout the study.

Another study examined bioburden at near-patient sites before and after cleaning.¹⁵ Here, screening was performed at half-hourly intervals for 7 hours after disinfectant cleaning; the bedrails beside six critical care beds were screened six times; and microbial growth was quantified as cfu/100cm² (we used cfu/cm²). Mean bacterial concentration on bedrails (n=36) before cleaning was 4,756 cfu/100cm², whereas mean ACC on cot-sides, locker and table (n=360) in this study was 4.3 cfu/cm². The log difference in microbial levels may be due to different sampling methods and their relative sensitivities.¹⁶

The pattern of viable staphylococci recovered over 48 hours provided the most striking difference between detergent and disinfectant cleaning (Fig. 3). Pre-clean MSSA/MRSA numbers were dissimilar between the studies, reflecting variable presence of staphylococcal carriers, but standardising the data reveals an unexpected surge in staphylococcal recovery 24 hours after disinfectant exposure. A previous study using hydrogen peroxide disinfection also reported rapid reappearance of MRSA within 24 hours.¹⁷ There is no obvious explanation for the rebound

contamination in this study, unless exposure to electrolysed water encourages hard surface biofilm to release viable planktonic staphylococci. Recent work has confirmed survival of MRSA within biofilm on dry hospital surfaces.¹⁸

The overall effect of neutral electrolysed water on surface bioburden at 24-48 hours was similar to that obtained after detergent cleaning (Fig 2). Electrolysed water could be useful for cleaning between patients in outpatient settings, since the speed and effect of disinfection would alleviate contamination concerns in busy clinics. For routine ward cleaning, however, detergent cleaning alone may be sufficient. Physical removal of bioburden appears to be just as effective as disinfectants for controlling environmental microbes.^{19-22,23} This is partially, but not fully, explained by the fact that the microbiocidal activity of a disinfectant is inversely proportional to the degree of organic soil on a surface.²⁴ More work is required to clarify this, because aside from cost issues, detergents are less toxic and unlikely to promote acquisition of resistance genes among environmental bacteria.²⁴

In conclusion, cleaning with electrolysed water reduced microbial load at near-patient sites on an acute ward. The reduction profile suggests that these sites should be cleaned once a day, since the time period before recontamination was about 24 hours. Overbed tables require greater frequency of cleaning. Further work is required to examine the relationship between disinfectant exposure and rebound contamination of MSSA/MRSA at 24 hours compared with detergent-based cleaning.

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Conflicts of interest

None reported by any of the authors.

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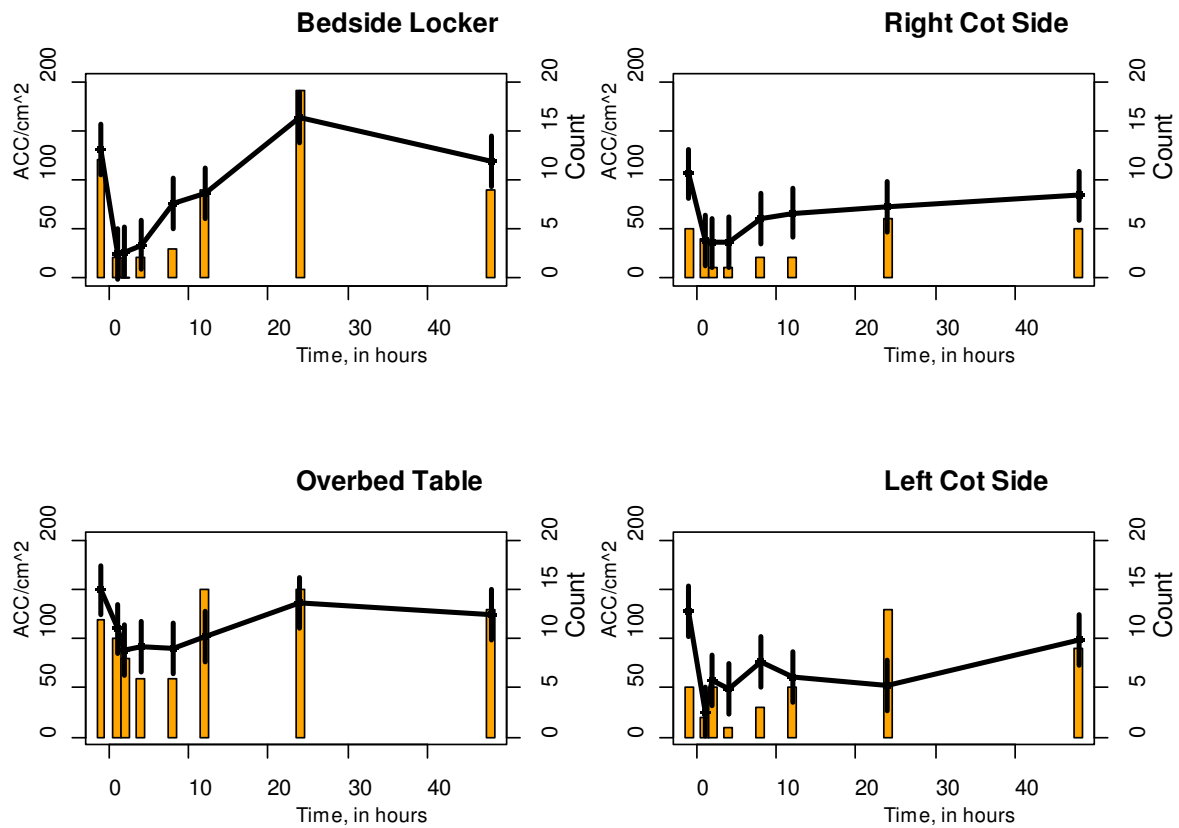
Figure legends

Figure 1: Aerobic colony counts (ACC)/cm² and total number of *Staphylococcus aureus* (MSSA) and methicillin-resistant *S.aureus* (MRSA) for all sampled sites over a 48 hour period before and after cleaning with electrolysed water (T=0).

Figure 2: Effect of detergent and disinfectant-based cleaning on total aerobic colony counts (ACC/cm²) at four near-patient sites on a 30-bed ward over 48 hours.

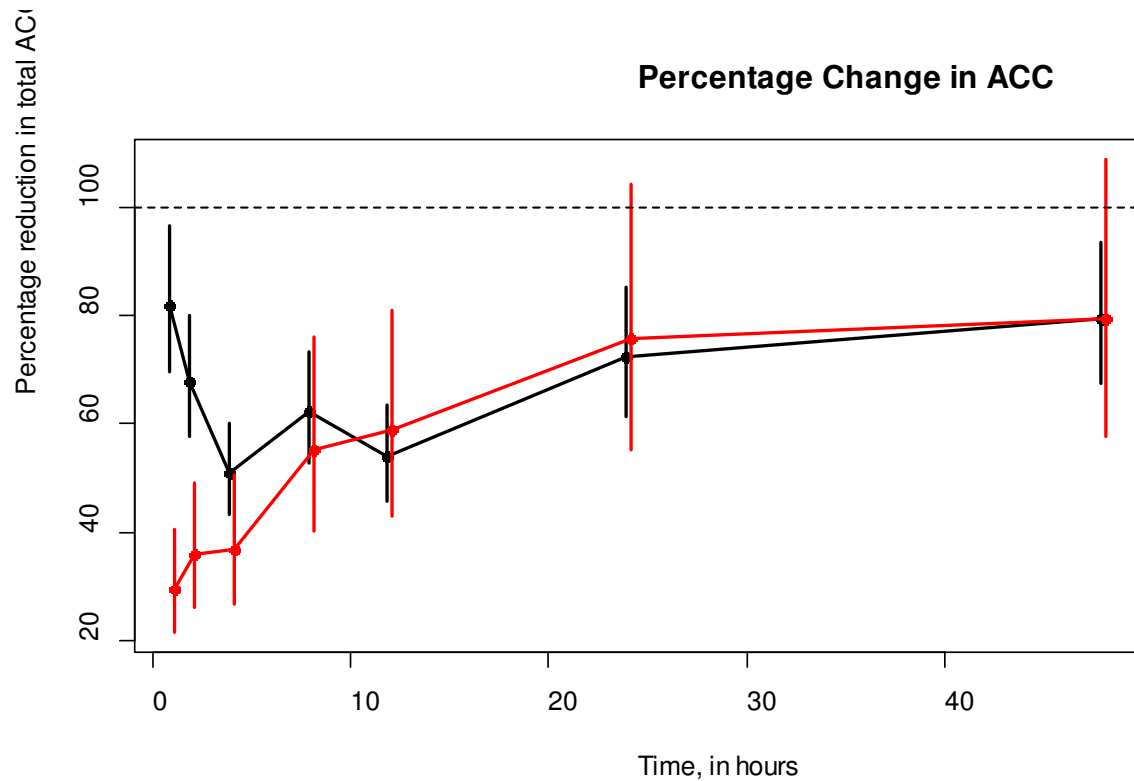
Figure 3: Effect of detergent and disinfectant-based cleaning on total *Staphylococcus aureus* (MSSA) and methicillin-resistant *S.aureus* (MRSA) recovered from four near-patient sites on a 30-bed ward over 48 hours.

Figure 1: Aerobic colony counts (ACC)/cm² and total number of *Staphylococcus aureus* (MSSA) and methicillin-resistant *S.aureus* (MRSA) for all sampled sites over a 48 hour period before and after cleaning with electrolysed water (T=0).



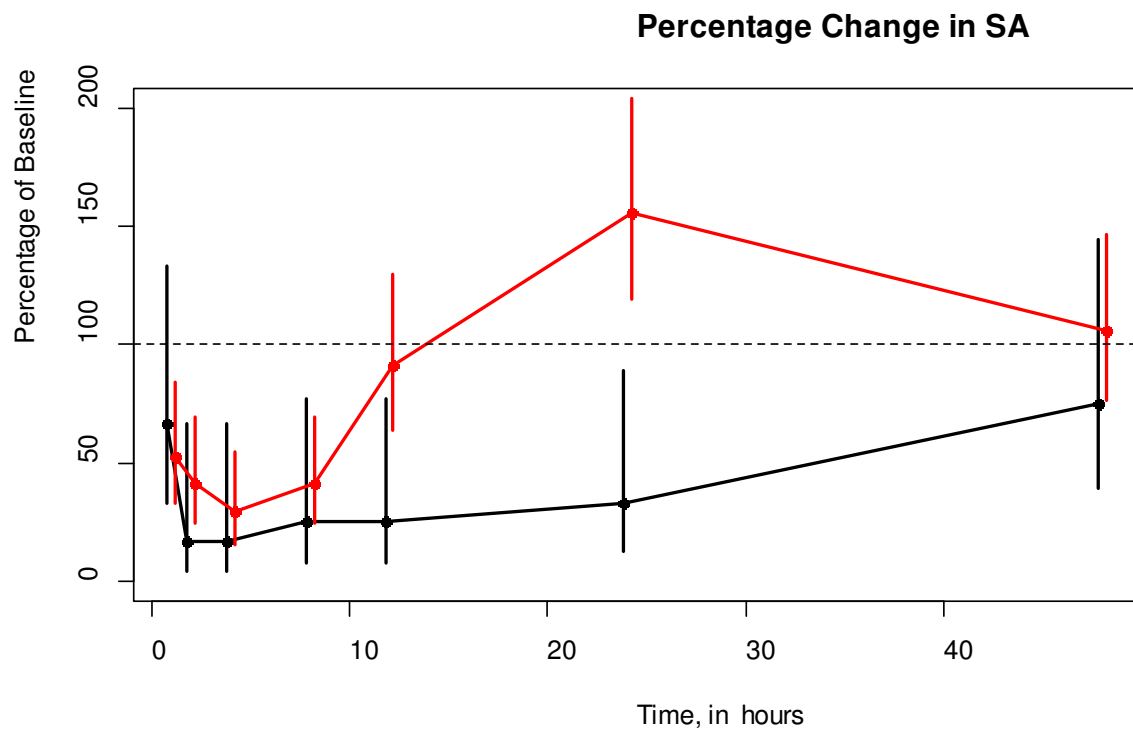
This plot shows the relationship between trends in ACC and MSSA/MRSA for each site averaged over three study phases. The black line represents ACC (LH axis), including the confidence interval for the mean based upon the linear regression model; the orange bars represent numbers of MSSA/MRSA (RH axis). The similarities in the trends are greatest for the bedside locker and over bed table.

Figure 2: Effect of detergent and disinfectant-based cleaning on total aerobic colony counts (ACC/cm²) at four near-patient sites on a 30-bed ward over 48 hours.



These are the estimated percentages relative to the baseline aerobic colony counts (ACC)/cm² derived from a statistical model of the log ratio of ACC at Time =1, 2, 4, 8, 12, 24 hours relative to baseline. The model accounts for differences between the three phases as well as time, and averages over the trends in the four sites. The detergent is plotted in black and electrolysed water in red. The vertical lines are the 95% confidence intervals for the percentage ACC relative to baseline.

Figure 3: Effect of detergent and disinfectant-based cleaning on total *Staphylococcus aureus* (MSSA) and methicillin-resistant *S.aureus* (MRSA) recovered from four near-patient sites on a 30-bed ward over 48 hours.



These are the estimated percentages relative to the baseline staphylococcal (SA) count derived from a Poisson regression model of isolate numbers of MSSA/MRSA at Time =1, 2, 4, 8, 12, 24 hours aggregated over site and phase including an offset for the log MSSA/MRSA and baseline. Detergent effect is plotted in black and electrolysed water in red. The vertical lines are the 95% confidence intervals for the percentage count relative to baseline.

Both types of cleaning rapidly reduced the overall staphylococcal burden, but recontamination occurred more rapidly after disinfectant exposure. The sites monitored were bedside locker, right and left cot sides and over bed table, and each type of cleaning was repeated three times.

Time (hours)	0 (Pre-clean)	+1 (Post-clean)	+2	+4	+8	+12	+24	+48
Total ACC/cm ² Site type								
1	131	24	27	37	75	86	163	118
2	106	38	27	36	68	67	72	100
3	150	110	88	92	90	103	136	125
4	128	26	58	49	78	61	52	99
Average ACC/cm ² Site type	129	49	50	53	78	79	106	110
Average ACC/cm ²	4.3 (4.37)	1.65 (1.71)	1.66 (1.37)	1.75 (1.37)	2.59 (1.87)	2.63 (3.21)	3.53 (2.87)	3.68 (4.21)
No. MSSA & MRSA Site type								
1	12	2	0	2	3	9	19	9
2	5	4	1	1	2	2	6	5
3	12	10	8	6	6	15	15	13
4	5	2	5	1	3	5	13	9
Total MSSA & MRSA	34 (12)	18 (2)	14 (5)	10 (3)	14 (4)	31 (4)	53 (13)	36 (8)
Average MSSA & MRSA	8.50	4.50	3.50	2.50	3.50	7.75	13.25	8.00

Table: Effect of three electrolysed water cleans on total aerobic colony counts (ACC)/cm² and MSSA/MRSA at high-risk sites on an acute 30-bed ward over a 48 hour period

KEY - Site 1: Bedside locker; Site 2: Right cot-side; Site 3: Overbed table; Site 4: Left cot-side

Hygiene standard <5cfu/cm²; (n) = Data from single-rooms (six beds)